UNIVERSITÉ DE MONTRÉAL

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AN OPEN INTERACTIVE GRAPHIC SYSTEM FOR DEMAND MODEL ESTIMATION

by

A. Babin, M. Dagenais, M. Florian, M. Gaudry,
J. Guélat, P. Lestage and T.C. Liem

CENTRE DE RECHERCHE SUR LES TRANSPORTS

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ABSTRACT

This article gives a summary description of TRIO, an open interactive graphic program developed for the formulation and simulation of **regression models belonging to three broad classes** and the **analysis of and reporting on** data and model results. The general design of the data bank and the structure of the program are described. Twelve model types belonging to the three classes of level, share and probability are surveyed and examples of graphic output are shown.

KEY-WORDS : INTERACTIVE GRAPHIC, SIMULTANEOUS LINEAR EQUATIONS, TOBIT, BOX-COX, LOGIT, DOGIT, INVERSE POWER TRANSFORMATION, PROBIT, AUTOCORRELATION, HETEROSKEDASTICITY, ELASTICITIES.

RÉSUMÉ

Nous résumons TRIO, un progiciel interactif graphique ouvert destiné à la formulation et à l'estimation des paramètres de **modèles de régression appartenant à trois grandes classes** ainsi qu'à **l'analyse et la fabrication de rapports** sur les données ou les résultats d'estimations. Nous décrivons la structure de la banque de données et du programme lui-même; nous rappelons brièvement les caractéristiques de douze types de modèles appartenant aux trois classes considérées des modèles de niveaux, de parts et probabilistes, et nous présentons quelques sorties graphiques.

MOTS-CLÉS : PROGICIEL, INTERACTIF GRAPHIQUE, ÉQUATIONS SIMULTANÉES LINÉAIRES, TOBIT, BOX-COX, LOGIT, DOGIT, TRANSFORMATION IPT, PROBIT, AUTOCORRÉLATION, HÉTÉROSCÉDASTICITÉ, ÉLASTICITÉS.

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1. INTRODUCTION

Over the past fifteen years, a number of statistical and regression estimation procedures have become widely used by various researchers in the social, engineering, medical and natural sciences. Most of these procedures have been implemented for use on modern computers, including microcomputers, in a "batch" type environment in which a set of data files often cannot be visualized before employment in the estimation procedures. Sometimes, the analyst can see a graphical display of the data file but must create the file beforehand, without having the possibility of visualizing the data prior to the creation of the file. Moreover, in the typical situation, only rudimentary traces of the data manipulations are kept and only standard results of the estimation procedure are printed out. Further analysis of the results requires special purpose service programs that must be written by the analyst and the outputs are not intended to be integrated in formal reports.

TRIO is an interactive-graphic procedure designed for the formulation, estimation and simulation of **regression models belonging to three broad classes** and the **analysis of and reporting on** data and model results.

In TRIO, a flexible dimension data bank is integrated into the procedure. Interactive sessions provide an easy way to manage the bank with real time graphic or non-graphic response. The dialog itself helps to expedite much of the exploratory data analysis and the very construction of the variables. Moreover, notes and comments can be kept on each variable as it is constructed.

The three classes of regression procedures available on TRIO contain many model types. Although very complex model specifications are possible, these can always be compared to simpler and more popular model

specifications; TRIO also keeps user notes and comments on particular regression experiments, in addition to model specifications and results. TRIO is an **open** system in the sense that users can exchange data files with other programs using standard formats and consequently have the option to use their own estimation procedures in addition to those available within TRIO.

Comments made in the course of constructing the variables or in specifying the experiments can be gathered in a notebook which may serve as a draft for the preparation of a final report. TRIO also contains extensive provisions for the interactive analysis and generation of tables of data and regression results. The notebooks, tables of results and graphs are directly usable in a report.

The computer science aspects of TRIO are based in part on the concepts and graphic subroutines that were developed for EMME/2 (1), an interactive-graphic urban transportation planning method. In the transportation planning context, TRIO provides demand model calibration procedures which are complementary to the use of EMME/2.

2. GENERAL CONCEPTS

The TRIO data base represented in Diagram 1 consists of multiple random access files. We note that :

- one file is used for each of the four types of **variables** admitted by TRIO : aggregate or disaggregate time series[1] and cross sectional observations. Indexed files, called tables, are associated with each type of variable and manage pointers into specific files containing values and descriptions of all variables of that type. For each type of variable, there is no predetermined space : the data bank is of a dynamic character;

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[1] By time series, we mean an ordered series of observations.

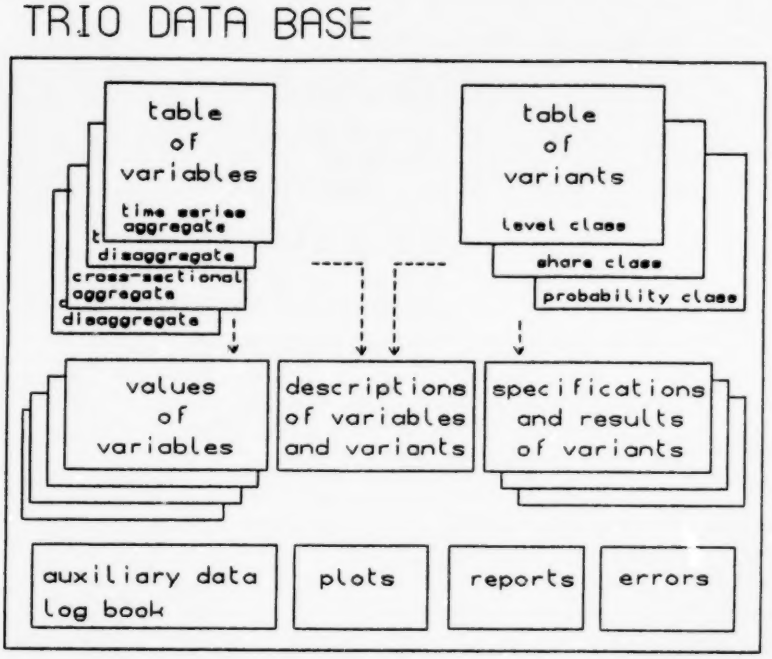


DIAGRAM 1

- similarly, a file exists for all regression experiments, called **variants**, made with any type of regression model belonging to one of three classes : the level, share or probability class. A table relates each variant to files containing the information pertaining to that experiment;
- **plots** and **reports** generated during a TRIO session are kept in corresponding files.

In a TRIO session, the user has available a set of modules that are organized into the five main groups indicated in Diagram 2 : the variable editor, the variant editor, estimation procedures, data and result analysis and utilities. Since the code is interactive, a TRIO user selects the appropriate sequence of modules for his/her particular needs. A typical TRIO session would involve the use of several modules from each of the module groups. Consider the following illustrative sequence :

- a user specifies a first regression problem by using the **variant editor** : a number of variables are chosen for a particular **estimation procedure**; the specification and results of the computations are kept in the data base with the variant specifications;
- the user performs an **analysis** of the results and decides to create a new variable from the existing ones, using the **variable editor**, and to specify a new variant which is the same as the previous one except for the addition of the new variable;
- the **variant editor** presents the specification of the first variant : it is readily modified by the simple addition of the desired variable to the existing list, and an **estimation procedure** is called ...

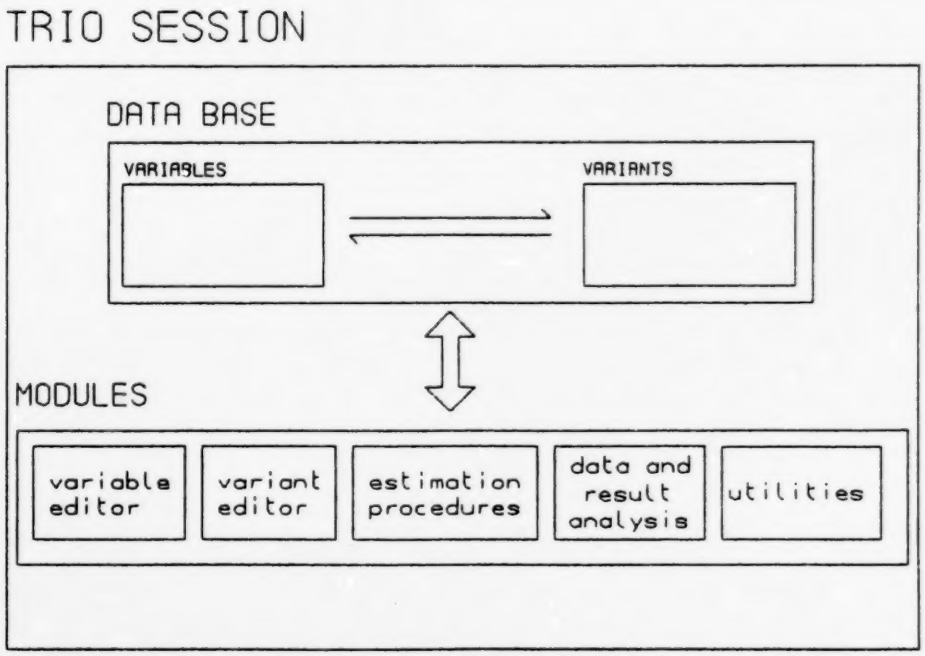


DIAGRAM 2

2.1. The variables

A variable corresponds to a set of attributes (name, status, etc.) and numerical values. It may be obtained from an existing data file, defined interactively, or created as an algebraic expression of existing variables in the TRIO data base. TRIO offers the possibility of modifying the numerical values of a variable : erroneous values can be easily corrected. The number of variables which may be added to the data base is not fixed by the code and is limited only by the space available on the mass storage device (disk).

The **name** of the variable plays a central role in the management of the information in the data base. This unique name of a maximum of twelve characters is used to access a variable and its contents. Special routines are provided in TRIO to manage a table containing the variable names and pointers which allow the efficient retrieval of all data associated with a variable. TRIO provides safeguards when deleting or creating variables. It prevents, for instance, the deletion of variables needed in an estimation procedure or used to generate other variables. Since mixes among the four types of variables are not allowed and a table is used for each type, a user working under operating systems which permit multitasking, such as VMS or UNIX, may simultaneously work on a table (say construct time series variables) while another task (e.g. the estimation of a model from cross sectional observations) occupies another table.

A **description** is supplied with each variable. It contains the fields shown in Diagram 3. For instance, the description allows the user to give two definitions of sixty-six characters which may be displayed on reports and graphic output. It also contains a comment field which may be of any desired length and include notes, comments, the history and

procedures pertaining to the sources, formulas and interpretation of the variable, etc. A user might, for any variable, enter many pages of information deemed useful for the intended construction of an appendix in a technical report where the variable is used. The description, which is accessible and may be modified any time that a variable is manipulated, is edited with a word processor which is an integral part of TRIO.

DESCRIPTION OF A VARIABLE

Variable name: XCANFA_____ Type: time series_, aggregate_____

Date: 18/11/85 User: JIM

Definition 1: number of adult trips _____

Definition 2: nombre de voyages d'adultes _____

Comments :

XCANFA is obtained by the multiplication of X, the observed total number of transit trips, by the share of adult tickets out of total ticket sales:

XCANFA = X * SHARE

DIAGRAM 3

In Diagram 4, the structure of variables is described. We note that a special file, which contains **formulas** used to construct variables, is shown. This file, which is a part of the auxiliary data file shown in Diagram 1, is not directly accessible to the user; it holds the information necessary for the automatic reconstitution of all variables (e.g. after an error is found, or a series is updated), the implementation of safeguards and the construction of genealogical trees showing the ancestors or descendants of any variable.

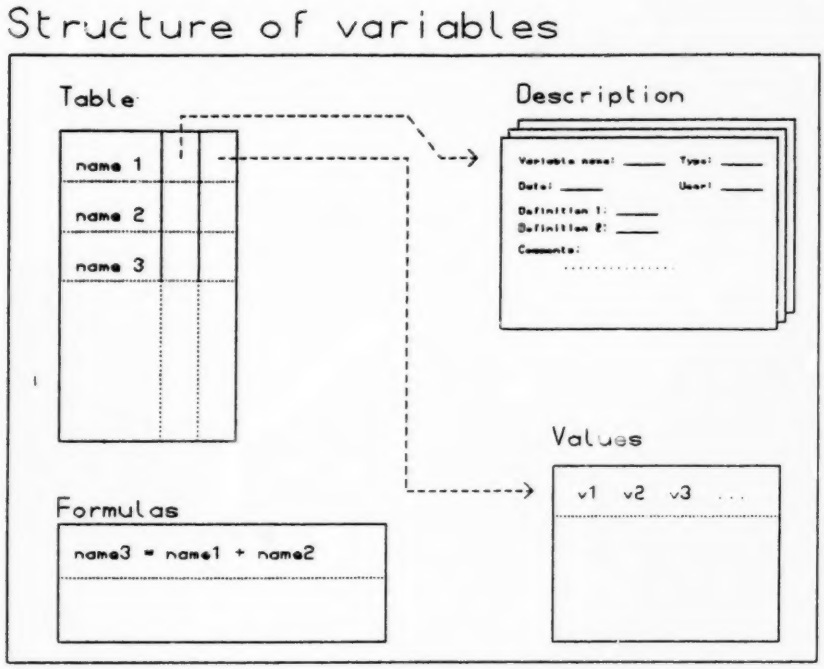


DIAGRAM 4

Assume for example that five variables, x1, ..., x5 have to be constructed. One would form algebraic expressions as follows :

x1 = shonf + sqrt(xcanfa)

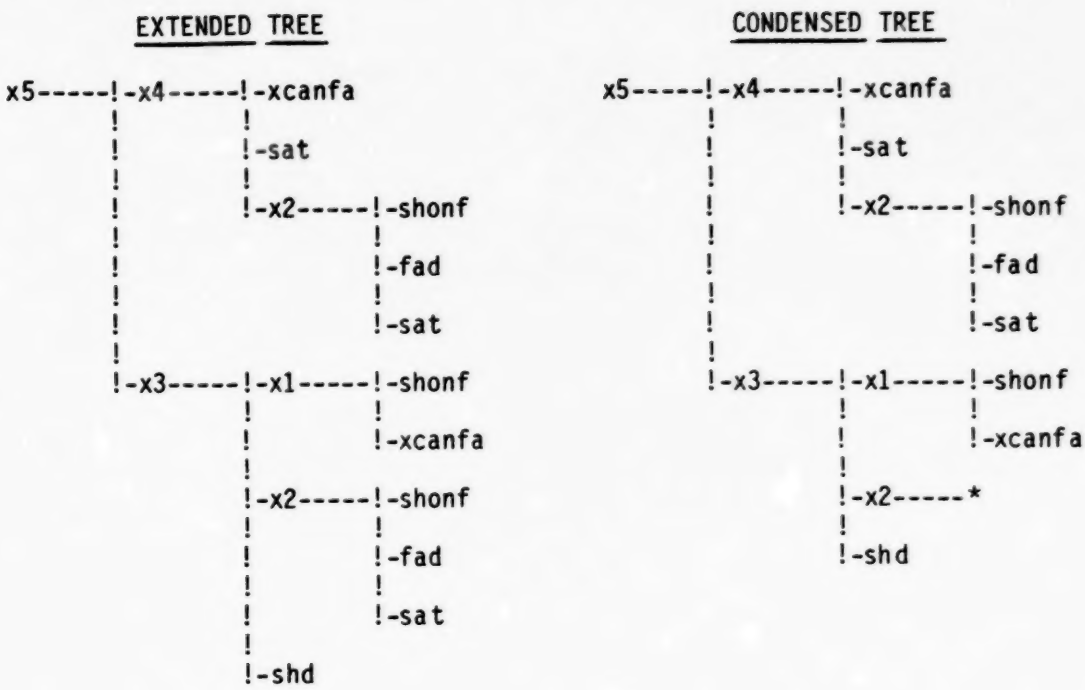
x2 = shonf + sqrt(fad * sat)

x3 = x1 - x2 + shd

x4 = xcanfa + sat + x2

x5 = ln(abs(x4)) + ln(abs(x3))

These easily written formulas would be kept by TRIO. If one needed later to see the **ancestors** of x5, one could ask either for the extended and/or the condensed tree (without repetition of branches already seen) of these ancestors (one could also have asked for the **descendants** in the same fashion), and obtain :



2.2. The variants

Within each **class** of regression models included in TRIO, a number of **model types** are available. The user chooses a model type and then completes the detailed specification of each experiment within the possibilities offered by the model type in question.

The conditions of a particular experiment (model type and detailed specification) define a **variant** within the class considered and TRIO maintains, for each variant, associated sets of **information**, including results, as shown in Diagram 5. Each variant has a **name** and a **version number**. These two attributes identify it completely. A modification of a variant automatically creates a new version. A user who initiates a new series of experiments would naturally create a new variant name; this variant automatically receives zero as a version number. A variant specification can be copied and modified easily.

A **description** is supplied with each variant name. Its format is similar but not identical to that used for variables; it is edited in the same way. The user may keep track of the rationale for initiating a variant series and of reflections concerning each version.

The results of an estimation procedure are used by the analysis module to generate reports and graphics. The user does not have to specify desired reports or graphics before an estimation. The user may compare results among variants.

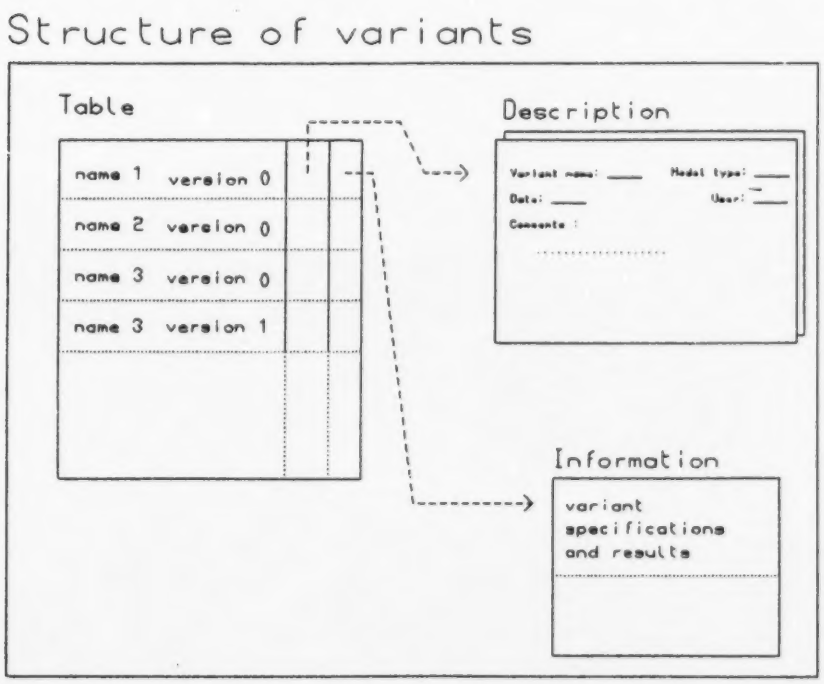


DIAGRAM 5

2.3. The estimation procedures

The three **classes** of regression **model types** available in TRIO are best explained by considering the following very general regression problem :

$$y_m = f_m (Y_m, X_m; \pi_m, u_m), \quad m = 1, \ldots, M,$$

where, for the m^{th} equation of interest, $f_m(.)$ is an unspecified function relating the continuous dependent variable y_m to vectors of other endogeneous variables Y_m and of exogeneous variables X_m; π_m denotes the parameters to be estimated and u_m denotes the error term.

With this general problem in mind, one can understand the formal definitions found in Table 1 :

- **classes** are defined by limitations on possible values of the y_m – on their individual range and on whether they must sum to 1 – due to the behavior of the set of regression functions considered and by the (continuous or discrete) nature of observations available on the y_m;
- **model types** are defined by further limitations on the range of observations and by constraints on the specific functional form of the $f_m(.)$. A specific functional form includes both a systematic part, involving the regressors, and a stochastic part, or model of the residuals.

In the outline which follows, we will give an idea of the planned model types, identified by their number shown in the last column of Table 1, and of their options.

THE LEVEL CLASS

Classical regression models belong to the **level** class. **Model types** of interest include :

L-2 : this procedure (2) is for a **single linear equation** model which contains endogeneous explanatory variables and multiple-order autocorrelation of the residuals. It basically combines ordinary least-squares with Box-Jenkins techniques to specify the appropriate multiple-order autocorrelation scheme and uses the Cochrane-Orcutt iterative solution technique to obtain the parameters. In two-stage least-squares terminology, the SSGAU option produces second-stage estimates and contains the least-squares option LSGAU as a special

TABLE 1

Definition of regression class and model type

	Values of the dependent variable y_m				Form of the $f_m(.)$	
	in the regression function		in the sample		in systematic and stochastic parts	
	$\sum_m y_m=1$	range	nature	range	#	name
LEVEL	NO	$-\infty<y_m<\infty$	continuous	$-\infty<y_m<\infty$	L-2	GAUSEQ
					L-3	GAUMEQ
				$L_1<y_m<L_2$	L-4	AUSEQ-T
		$0<y_m$		$0<y_m$	L-1.1	BC-GAUHESEQ
SHARE	YES	$0<y_m<1$	continuous	$0<y_m<1$	S-2	BC-LOGIT
					S-3	DOGIT
					S-4	IPT-LOGIT
PROB.	YES	$0<y_m<1$	discrete	$y_m=0$ or 1	P-1	PROBIT
					P-2	BC-LOGIT

Defines CLASSES **Defines MODEL TYPES**

case; both can be used with or without the generalized autoregressive model of the residuals.

L-3 : this procedure (3) pertains to **multiple linear equations** in which each equation has its specific generalized autoregressive model of the residuals. When equations are grouped in order to take into account the contemporaneous correlation among the residuals of different equations, two estimation techniques can be used :

i) ISUGAU, an iterated version of Parks' (4) seemingly unrelated procedure generalized to multiple-order autocorrelation cases;

ii) TSGAU, an iterated third stage of a three-stage least-squares generalized autoregressive estimator applied after second stage regressors have been obtained for each equation separately and independently.

If, by contrast, equations are considered simultaneously, two techniques can be used :

iii) IFIVER, an iterated version of Fair's (5) full-information instrumental variables efficient estimator;

iv) MIFIDA, a modified iterated version of Dhrymes' (6) full-information dynamic autoregressive estimator.

The TRIO user can obtain non-iterated versions of the above four estimators by requesting only one iteration.

In contrast with these classical model types, many data sets incorporate limitations on observed values of the dependent variable. Origin-destination matrices of aggregate transportation flows, for instance, are typically extremely sparse and contain a large number of null observations. In other sets, the dependent variable, such as the number of transit trips per year in a large urban area, is always positive. In these situations, and assuming that there are no endogeneous explanatory variables, a TRIO user might, respectively, use :

L-4 : this procedure (7) allows for parameter estimation of a **single linear equation** TOBIT model with first-order autocorrelation. This model allows for the explicit recognition of a lower limit L_1 (0 in the case of an origin-destination matrix) and of an upper limit L_2, if necessary, in the data. The explicit recognition of such mass points means that L-4 is a censored model type, as Maddala (8), for instance, uses the notion of censoring.

L-1.1 : this procedure (9), for **single equation** model estimation, consists of a Box-Cox regression with multiple-order autocorrelation and a very general form of heteroskedasticity which includes as nested special cases most forms used in practice. Distinct Box-Cox transformations can be used on the dependent variable, on groups of explanatory variables and in the model of heteroskedastic residuals. The procedure assumes that y_m is a priori a doubly censored variable but that the actual data used for model estimation includes no limit (mass point) observations; it verifies a posteriori the validity of this assumption by calculating the probability that each observation be at the limits.

THE SHARE CLASS

All **model types** which belong to the **share** class include the simple LIN-LOGIT, i.e. the classical LOGIT form with **linear-in-parameters** "representative utility" or exponent functions, and estimated only from data sets for which none of the observed share values is null. In consequence, this lowest common denominator option can be compared to the more complex **additional** possibilitities offered by each TRIO model type of the share class, namely :

S-2 : the supplementary dimensions of this procedure (10) arises through the fact that the BOX-COX-LOGIT is defined by adding Box-Cox transformations on all variables of a LOGIT. This makes possible the use of identical sets of explanatory variables in all exponent functions, an option that can be called the EXTENDED, or GENERALIZED, formulation. The STANDARD option is defined by using the same sets of explanatory variables as those one would use in the LIN-LOGIT.

S-3 : in the DOGIT model, which exists in a GENERALIZED (11) and STANDARD options, the additional parameters make the attractions of each alternative a function of the characteristics of all alternatives.

S-4 : in the INVERSE POWER TRANSFORMATION-LOGIT (12) model type, additional parameters represent captivity to alternatives and can make the shape of the response curve asymmetric. Moreover, they also allow the user to specify an EXTENDED formulation by the use of identical sets of explanatory variables in all exponent functions; a STANDARD option is defined by using the same sets of explanatory variables as those one would use in the LIN-LOGIT.

THE PROBABILITY CLASS

In both the **probability** class and the **share** class, the expected value of the dependent variable y_m can be viewed as the probability of a particular state. These classes differ, however, in the observed realizations of the state y_m : in one case, shares are observed; in the other, mutually exclusive choices are observed, typically in the guise of non ordered categorical data : given binary values, they are often called "disaggregate" data. The model types found in TRIO include :

P-1 : a PROBIT procedure.

P-2 : a BOX-COX-LOGIT procedure like S-2, which includes EXTENDED and STANDARD options, as well of course as the LIN-LOGIT (13) nested special case.

2.4. Data and result analysis

GRAPHIC TOOLS FOR EXPLANATORY DATA ANALYSIS

Information available in the data base, such as explanatory variables of a model or estimated regression residuals obtained from variants, can be plotted. Standard plots are available but the format of a plot is not fixed : the user can produce complex or simple plots, specifying the contents of a plot as it is generated, for instance by requesting that more than one variable be displayed on a given plot.

A **graphic editor** provides a user friendly way to manipulate plots. This manipulation is available both on the objects that compose the plots and on the plots themselves. Interactive manipulation of objects means that every part of a plot can be selected and translated, rotated, scaled, ..., or have its color or line representation changed; the user can also add to plots any desired text, polygons, axes, ... Manipulation of the plots themselves means, for instance, that one can select a plot to work on. Moreover, each plot has its own viewport : separate plots can be displayed simultaneously, successively, or superimposed on the screen surface. The user wishing to enlarge a plot to obtain greater visual accuracy can do so with a zooming feature.

In contrast with a "batch" code, where each successful execution terminates with a particular set of results, the interactive code allows the user to obtain results of different kinds during a particular TRIO session. For instance, the variable currently displayed can be produced as a plot or as a set of numerical values.

SPECIFIC TABLES

The estimation of variants produces various results, some of which are automatically kept by TRIO while others are easily recomputed upon user intervention. The user may present many of the results, or for that matter any variable, in table form : with time series data, for instance, it is often natural to look at **calendars** of values.

Specific formats are available for the presentation of the results of variants in **tables of estimation results** directly usable in a report. For instance, the user might put the definitions of variables, drawn from the descriptions file, in a first column of explanatory variables rather than simply list the names of the variables; in the next column, the user might put the regression coefficients and their standard errors, or the elasticities and the standard errors of the regression coefficients.

The user can make tables of **elasticities, defined in both intuitive and strict fashion** according to (14), for all explanatory variables of a model, including dummy variables, and select the points at which the elasticities are evaluated. The possibility of reading tables of elasticities, rather than coefficients, for all variables of a variant, and of comparing results of selected variants in the same table, greatly decreases the task of selecting an appropriate model.

2.5. Utilities

At present, the utilities available to a TRIO user consist of an automatic **Log Book** that keeps record of the identity of the user and of the modules and elements of the data base used during previous TRIO sessions. Since the entries in the Log Book are limited, the kinds of past utilizations indicated in the Log Book are prespecified. The planned utilities include a **garbage collection** procedure for the periodic compression of the data bank.

3. THE OPEN COMPUTER BASED SYSTEM

TRIO has been coded in standard FORTRAN'77 and, as EMME/2, has been designed for easy transferability to various computer makes. It has been developed on an MC 68000 super-microcomputer operating under UNIX at the **Centre de recherche sur les transports** of the **Université de Montréal,** however it may be adapted easily for other micro and minicomputers. It will be available in IBM/PC and IBM/AT versions using 32-bit acceleration boards.

The TRIO code has a modular structure. Each of the modules is an independent program but all the modules share the TRIO subroutine library. All data transfers among modules occur only via the data base. Diagram 6 gives a schematic representation of the program structure. Data files can be exchanged with other estimation programs and results can be retrieved and used within TRIO.

At present, TRIO supports the use of a wide range of monochrome and color graphic terminals : the Tektronix series, the Visual 550, the SEIKO GR-1104 and Lexidata. Any output displayed on the monitor's screen may be copied on a hard copy unit or on a matrix dot printer. The same output may be drawn on high resolution plotters such as CALCOMP, Hewlett-Packard or Tektronix. TRIO may be easily adapted for use with other graphic equipment of comparable resolution.

4. SOME OUTPUT EXAMPLES

TEXT

As procedures for the production of **reports** are still under development, we can only give an idea of projected features. We have already mentioned the ability to make **note-books** from descriptions of

variables and variants, **genealogies** such as that of in Section 2.1, and **tables** of variables and results. The format of tables of regression results will be inspired from that found in recent reports (14, 15) that include tables of elasticities and t-statistics of various models estimated by procedures incorporated in TRIO. **Lists** of variables, variants, algebraic expressions or other contents of the data bank can also be produced.

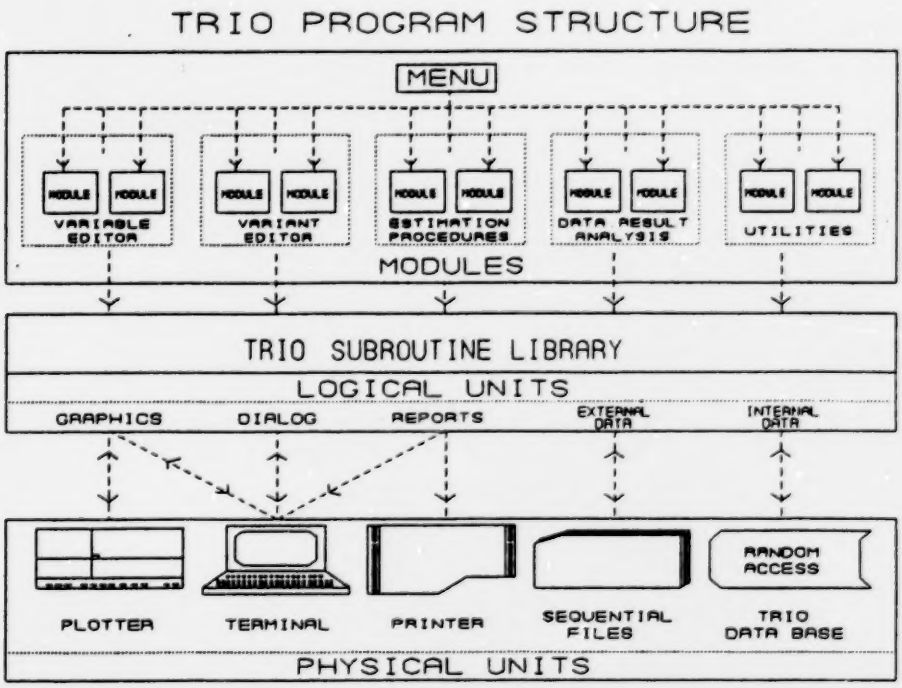


DIAGRAM 6

GRAPHICS

Figures found in this section are current samples of **graphics** procedures : their final format may differ from that presented here.

Figure 1 Shows the dependent variable of an aggregate monthly time series model, the number of adult trips, and one of the explanatory variables, the real retail sales index.

Figure 2 Shows the real retail sales index.

Figure 3 Shows the distribution of values of the real sales index.

Figure 4 Shows two graphs. In the first one, forecasts of the dependent variable XCANFA (the number of adult trips) are made by two methods in the time period that follows immediately the sample period used for estimation purposes. The next graph shows the actual values of the dependent variables during the forecast period. The two graphs could be superposed.

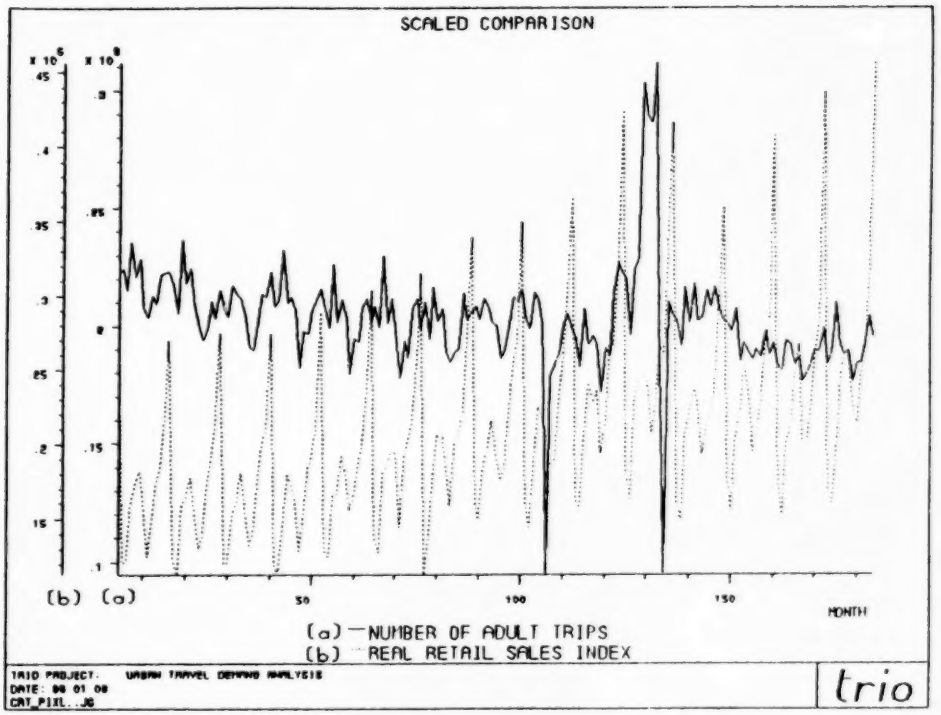


Figure 1
Number of adult trips and real retail sales index

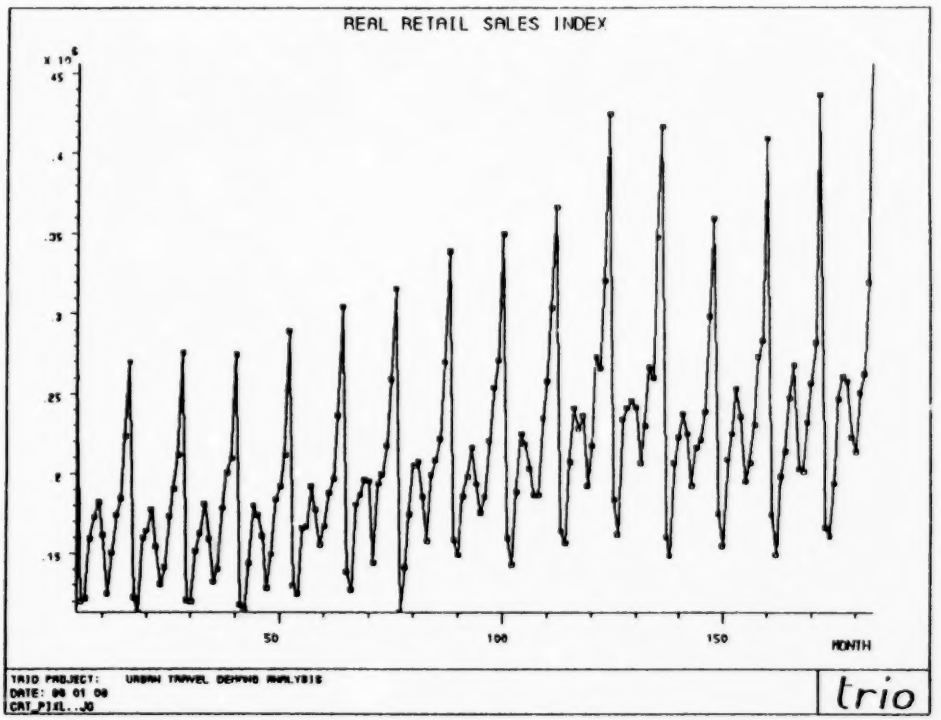


Figure 2
Real retail sales index

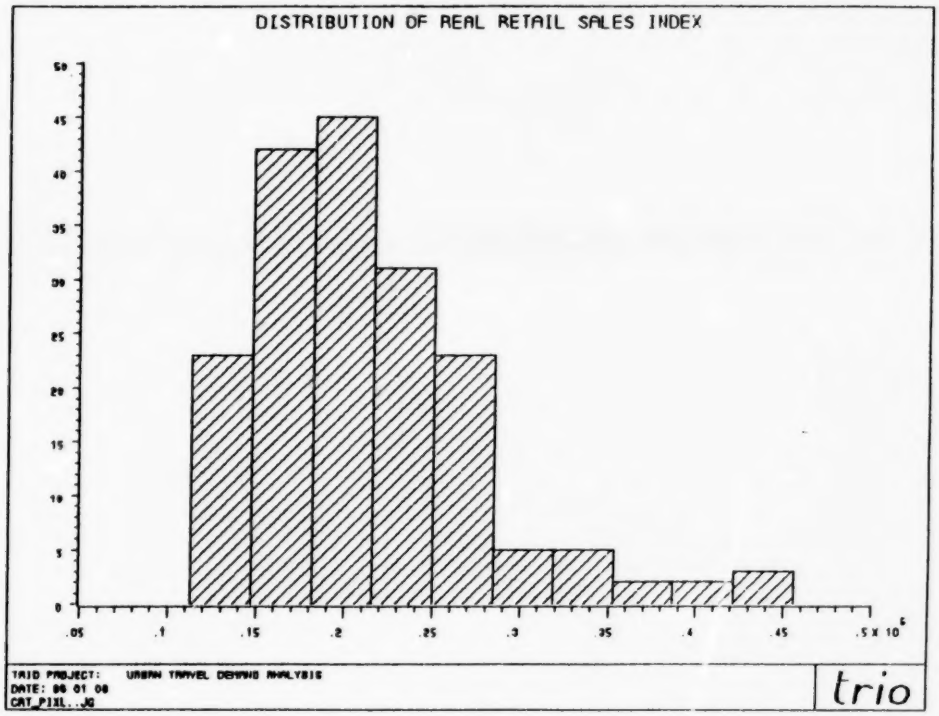


Figure 3
Distribution of real retail sales index

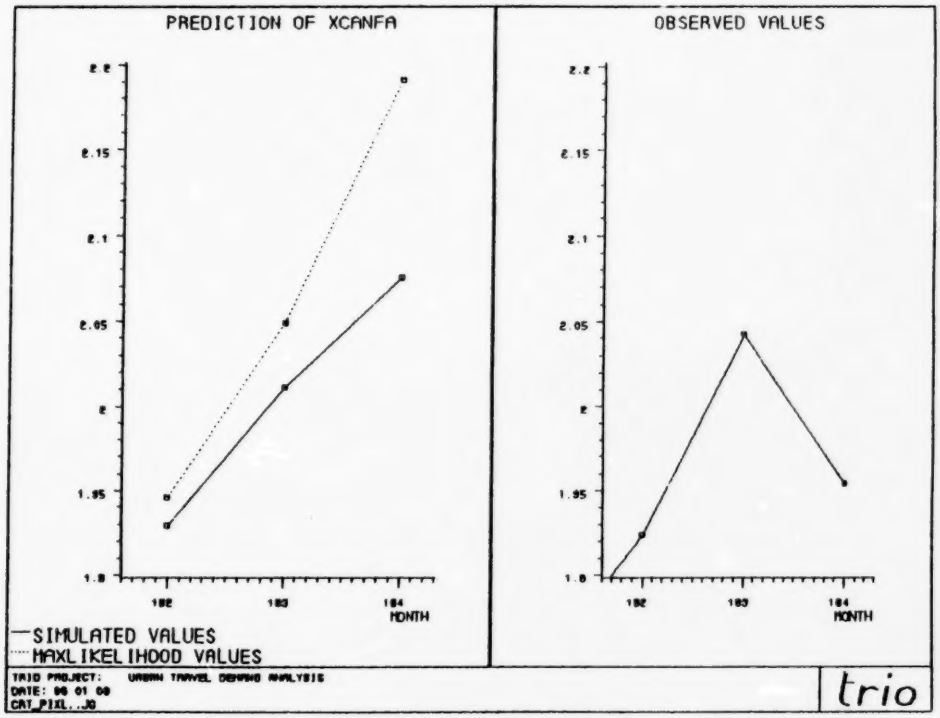


Figure 4
Prediction of XCANFA and observed values

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